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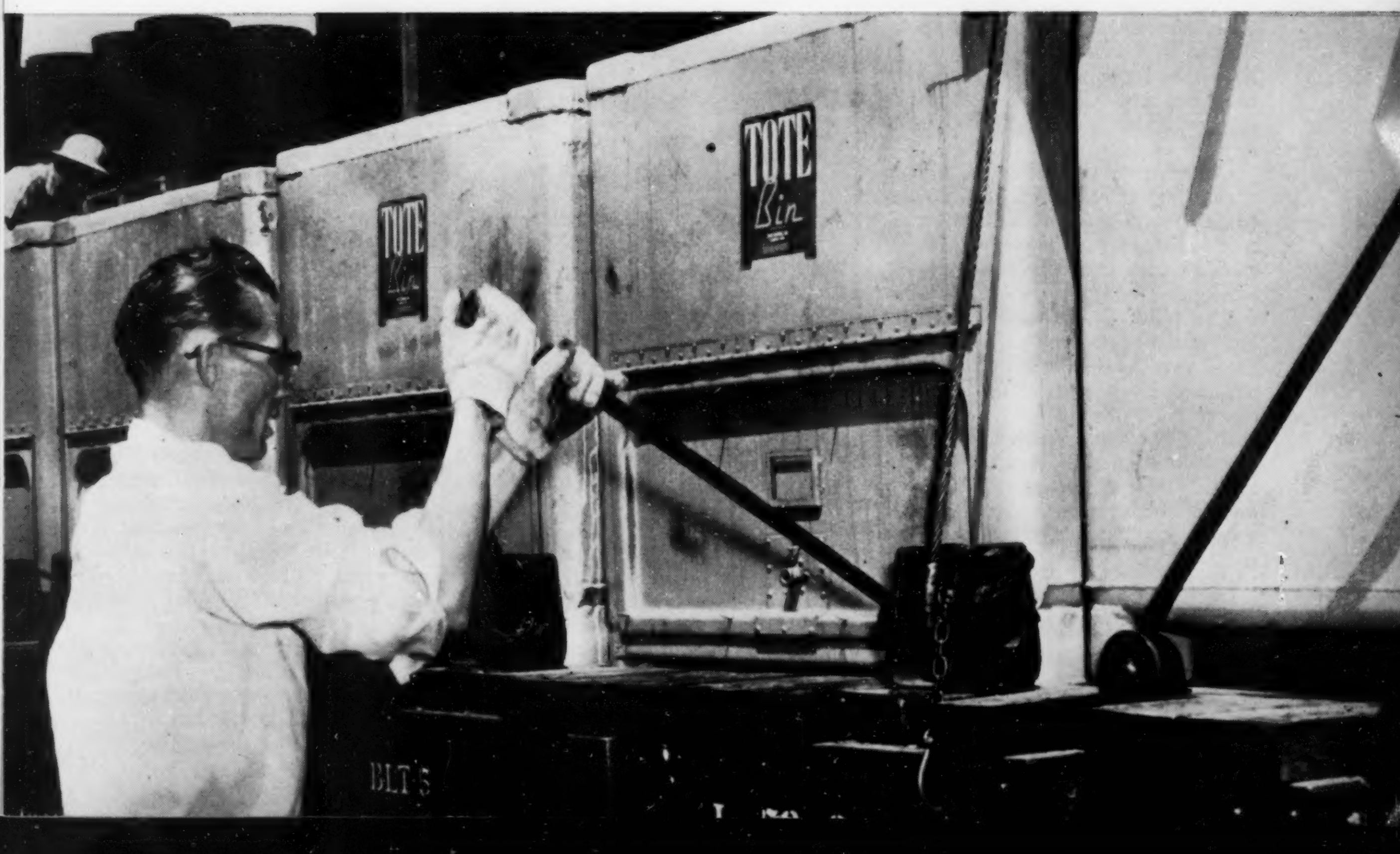
Thixotropic Property of Lubricating Grease

By H. UTSUGI, K. KIM, T. REE and H. EYRING

Future Package Trends and Designs for Lubricating Greases

By F. W. LANGNER



CLIMAX MOLYBDENUM

Molysulfide® News Digest

CLIMAX MOLYBDENUM COMPANY, a division of American Metal Climax, Inc., 1270 Avenue of the Americas, New York 20, N.Y.

RECENT TEST SHOWS MORE PROOF OF MoS_2's LOAD-CARRYING ABILITY

Grease Compounders Take Hard Look At Paste Type Concentrates

In a recent issue of NLGI SPOKESMAN, a prominent lubrication authority warns that in the future an increasing number of the newer machines will be greased "for life"—or for long lubrication intervals. He also says that as the industrial pace quickens and wages go up, it will be more economical to use more expensive grease and reduce lubrication frequency.

That's why grease compounders and blenders are looking into every possible way to maintain and increase their profit levels.

High on investigation priority lists are the paste type concentrates. These concentrates contain solid lubricants. Molysulfide concentrates can be applied by grease guns or by brushing, and will stand up at temperatures as low as -100 F. and peaks as high as +500 F.

Concentrate users include a fast spreading number of industries. Major manufacturers in the automotive industry use paste type Molysulfide concentrates for pre-assembly lubrication of splines, cams, etc.

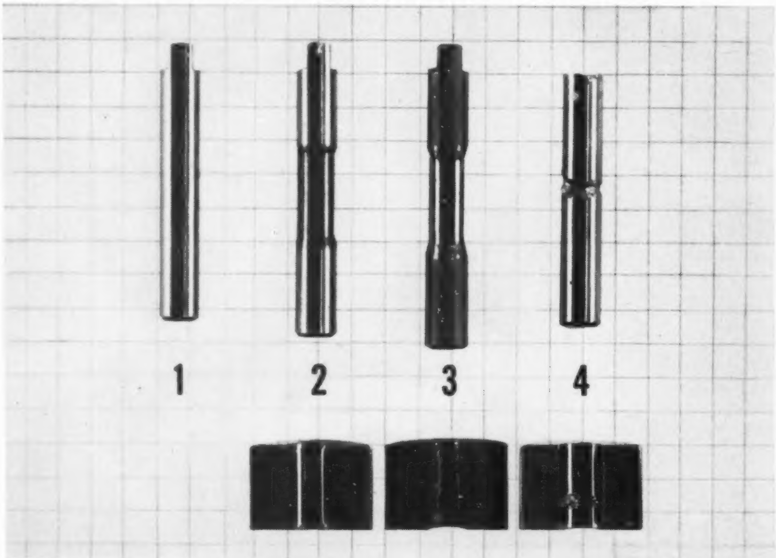
The aviation and missile industry is using an increasing amount to overcome low-temperature problems in servo-mechanisms, bearings and gears.

General industry is applying them, not only on metals exposed to continuous high temperatures, but also on plastic bearings, machine tool ways, press fittings and other moving parts where long lubricant life and high load carrying capacity is needed.

Much remains to be learned about the full potentialities of paste type concentrates but all signs indicate they are one of the answers to lubrication problems of the future.

When writing, refer to CL-110

From the German laboratory of Alpha Molykote Corporation comes new proof of Molysulfide's ability to resist galling and seizing at pressures beyond the yield point of most metals. Previous tests have shown that Molysulfide provides positive protection up to 475,000 psi. In this Alman Wieland test, similar to the Falex test, a ¼-inch pin actually extruded *without any surface damage* at pressures of 100,000 psi, while those using other lubricants were torn, galled or "frozen" to the point of breakage.



Photograph above shows mild steel test pins. No. 1: unused pin. No. 2 (lubricated .with mineral oil and Molysulfide) and No. 3 (with Molysulfide bonded coating) were subjected to rotating pressures between bearing halves. Both were elongated and extruded without galling, seizing, or weight loss. No. 4 shows typical failure with conventional lubricant. Note that the key sheared off and pin and block were galled and seized.

Extensive surveys among a great many independent laboratories indicate that the extrusion phenomenon produced with Molysulfide has never been achieved with any other conventional lubricant.

This proven load carrying ability of Molysulfide is only one of the reasons why grease compounders and lubrication engineers are investigating and testing new uses for MoS_2.

Other reasons include its extremely low coefficient of friction; its wide temperature range from -300 F to 750 F; its tenacious adherence to metal surfaces and a resultant great resistance to "scrape-off" and "wash-off"; and, its high chemical stability combined with long-life characteristics.

The uses for solid lubricants are multiplying. And—by test—Molysulfide is the superior solid lubricant.

When writing, refer to CL-111

nlgi spokesman

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IN THIS ISSUE

THE COVER

A SIMPLE winch is used to fasten these bulk "Tote Bins" on a railroad flat car for distribution around the country. In addition to discussing modern methods of handling grease in bulk, F. W. Langner, in his article "Future Package Trends and Designs for Lubricating Greases," covers changes in the construction of different size grease packages and gives data showing the effect of these changes. For a discussion of what is being done to bring down or keep the cost of grease packages from rising, please turn to page 132.

NLGI PRESIDENT'S PAGE

By F. R. HART, *President*

Atomic Power and Lubricants Needed in the Year 2000

The forecast that follows provides further information on the lubricating greases of tomorrow. The forecaster chooses anonymity and of course, we are respecting his request. The points raised are good ones and serve very well to round out the thoughts expressed by our other three contributors.

One must contemplate machines of the year 2000 before he can predict the type of grease that may be in use. It is to be expected atomic power will supply a substantial amount of the electrical energy. Most of this will be from fission reactions; however, fusion energy may also be a factor. Atomic energy will not only be used to generate electricity, but also may be used to propel ships, perhaps trains and even airplanes. Thermionic devices and magnetohydrodynamic generators may be a practical source of electricity. Fuel cells will probably be common. Supersonic planes will carry both passengers and freight. Electric motors will be smaller and run at higher speeds and temperatures. General industrial plant bearings will run hotter because of higher processing temperatures and higher bearing speeds and loads. A substantial number of cars and trucks may be propelled by gas turbines or electric motors with fuel cells or light rechargeable batteries supplying the electric power.

In the year 2000 special high temperature greases will represent the big advances. Here, costs will not be so restrictive in the choice of materials. Space ships will demand higher levels of performance in high temperature stability, low temperature plasticity and low volatility. Radiation-resistant greases will be available which are capable of operating within the temperature range of -100° F. to 500° F. while being exposed to as much as 10 billion roentgens of gamma rays or neutrons. Other special greases in the absence of radiation will span a temperature range of -100° F. to $+700^\circ$ F. To meet extreme temperatures, the greases will be prepared with such fluids as polyphenyl ethers and perfluorophosphoronitriles and thickened with such materials as inert inorganic particles and highly condensed aromatic compounds. Inorganic polymers will be used in special cases for higher temperatures. Even with the use of these materials in product formulation, it is expected the demand for radiation-resistant grease will be relatively small.

The low-temperature requirements of general purpose greases needed in the year 2000 will approximate present-day lubricants. However, the high temperature limits will be raised to permit lubrication at 350° F. or higher for long periods.

What will be the composition of the new general purpose grease? Mineral oils will be the fluid component of the big volume greases because the laws of economics will still be in force in the year 2000. The oils will be specially refined. More potent oxidation and rust inhibitors will be used. New thickeners will be required to meet the high temperature needs. These thickeners will be largely synthetics possibly related to the terephthalamates and aryl ureas of today.

Announcement of the 30,000-mile passenger car lubrication interval has had a very profound effect on the people in the lubricating grease industry. This is as it should be, as occasionally all of us are inclined to coast along in the belief that "everything is fine" and will continue to be so. Because of this attitude and the many conversations that have come to my attention, I decided to look into the future of our business. In summary, this is what I found:

1. We will be in business for another 40 years at least, making and selling improved versions of present-day multi-purpose lubricating greases.
2. Either we or the chemical industry will be making and selling special, exotic type lubricants for use in airborne or atomic-powered equipment.
3. Increased product research is an absolute must to solve new machine lubrication problems and to assure a safe position in the lubricating grease market.
4. The market will be larger as machines will work longer to take care of the needs of an ever-expanding population.
5. Product profits will improve as the lubricants needed will be of far better quality than those presently in use. ■

News About NLGI

Pars Oil Joins NLGI

Pars Oil company, Teheran, Iran, has joined the Institute as an Active member firm. Abdolali Farmanfarmaian, chairman of the board, will act as NLGI Company representative.

Waghorn Named BP's Technical Representative

BP (North America), an Active member, has placed P. S. Waghorn as NLGI Technical representative, replacing G. N. Griffiths, who has returned to England.

R. V. Lewis Is Skelly's Company Representative

Skelly Oil company has named R. V. Lewis as Company representative. He succeeds C. E. Gore, who is retiring. Lewis is also becoming superintendent of the lubricating division of this Active member firm, upon Gore's retirement.

New Research Fellowship Sponsored by NLGI

Mr. E. L. Armstrong, chairman of the NLGI Sub-committee on Fundamental Research, has announced the sponsorship by the Institute of a new research fellowship on non-Newtonian Flow in Bearings, beginning with the academic year in September, 1961.

The proposed research will be conducted by the chemical engineering department of Northwestern University, Evanston, Illinois, under the guidance of John C. Slattery, assistant professor. The program has as its broad objective the analysis of flow of non-Newtonian fluids in bearings. It is anticipated that for the first year the study will be limited to an infinitely long journal bearing filled with a grease described by the Sisko model. The desired results would be the effect of grease properties and eccentricity upon velocity distribution, pressure distribution, load carrying capacity and friction. It is hoped that this research will result in improved procedures in bearing design, and a better understanding of the behavior to be desired in greases.

Prof. Slattery

This will be conducted by the Fellow, a research student, under the guidance of Professor Slattery. The program will continue throughout the academic year and into the summer.

This research program is in addition to an earlier fellowship being conducted at the University of Utah under Dr. Henry Eyring, on rheology.

NLGI has issued grants since 1951, to assure industry progress and build an increasing pool of scientific knowledge—as the insurance of progress for members of the industry.

SERVICE AIDS

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BALL JOINT BOOKLET — "Recommended Practices for Lubricating Passenger Car Ball Joint Front Suspensions." The latest aid in application, created by experts in the field and designed for use in the station. Twelve pages, easy to read, with large illustrations throughout. Twenty-five cents a copy with quantity discounts—company imprint arranged.

WHEEL BEARING MANUAL — "Recommended Practices for Lubricating Automotive Front Wheel Bearings." More than 170,000 copies of this booklet have been distributed throughout the world. Now in its sixth printing. Sixteen pages, with more than 40 illustrations. Twenty-five cents a copy, with quantity discounts — company imprint arranged.

FOIL SEALS OF NLGI'S NEW PROMOTION CHARACTER— Aluminum foil stickers, measuring one by one-and-a-half inches, show NLGI's little man in full color . . . add a distinctive touch to correspondence, advertising, etc. Box of one thousand, $7.50, postage paid.

NLGI MOVIE — "Grease, the Magic Film," a 16-mm sound movie in color running about 25 minutes, now released. First print $300, second and subsequent orders $200 each (non-members add $100 to each price bracket).

Thixotropic Property Of Lubricating Grease

By: H. Utsugi, K. Kim, T. Ree and H. Eyring
University of Utah

Presented at the NLGI 28th annual meeting in Chicago, October, 1960

I. Introduction

It is well known that grease, which is composed of mineral oil and thickener (soap, silica gel, bentonite, etc.), presents non-Newtonian flow property as well as thixotropy.[1] By incorporating the technique of electron microscopy into the study of grease, the structure of thickeners in grease is fairly well understood; for example, the thickeners in soap grease and silica gel grease show entangled fibers and corpuscular aggregates, respectively.[2] The flow properties of grease are considered to be very dependent upon the structure and properties of the thickeners. In order to study the effect of thickeners on the flow properties of grease, we used greases in which the thickeners were well studied; and we determined the flow curves (shear rate $\dot{s}$ versus shear stress f) of the greases by using an autographic rotational viscometer.[3] The results are given below, and are considered in terms of the theory of rate processes.

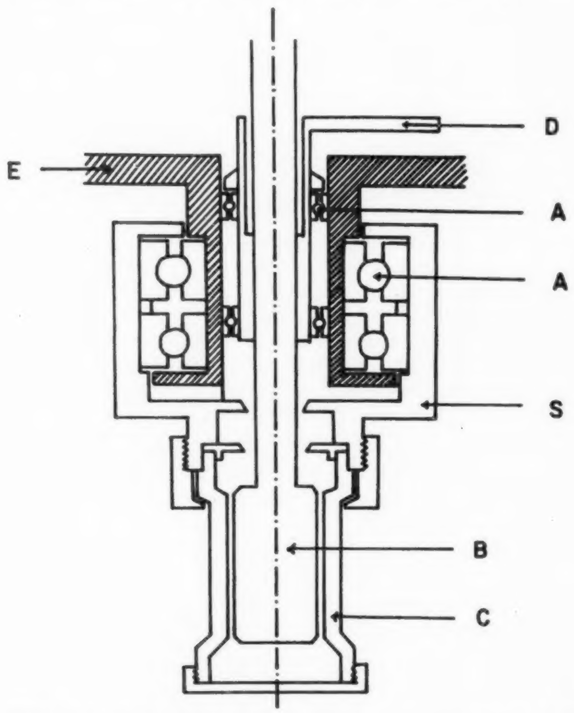

FIGURE 1—Main portion of the rotation viscometer. A, ball bearing; B, bob; C, cup; D, arm connected to a transducer; E, support; S, steel case. Samples are sheared between B and C.

II. Apparatus and Materials

The essential part of the autographic rotational viscometer, which was constructed in this laboratory,[3] is shown in Figure 1. In the studies of highly viscous fluids, such as concentrated high polymeric solutions, lubricating grease, etc., the frictional heating of the materials in the annular space between the cup and bob is not negligible.[4,5] In order to avoid the heating effect, the water in the thermostat, into which the cup-and-bob part is immersed, is circulated inside the bob. Preliminary tests showed good results for eliminating the frictional heating by this device.

Two kinds of greases were used. One is typical commercial lime soap grease (NLGI No. 2) furnished by the Utah Oil Refining Co.*; this grease was diluted with commercial High Vacuum Oil† when necessary.

* The composition of the grease is as follows: 80 Vis bright stock, 48.25 per cent; Edible tallow, 10.68 per cent; Beta fat, 31.47 per cent; Hydrated lime, 6.48 per cent; Paratac, 3.12 per cent.

† Commercial oil for high vacuum oil pumps; viscosity: 9.4 poises at 30° C.

TABLE 1

Composition (Weight Per Cent) of Silica Gel Greases

CALRESEARCH NO.	588	589	590	591	592
Santocel C[a] (%)	10.0	8.0	6.0	4.0	2.0
Ucon lubricant LB-1145[b] (%)	1.0	0.8	0.6	0.4	0.2
Mineral oil[c] (%)	89.0	91.2	93.4	95.6	97.8
ASTM worked penetration	295	332	375	460	510

(a) Silica gel made by Monsanto Chemical Co.

(b) Polyglycol marketed by Union Carbide Chemical Co.

(c) A bright stock; viscosity: 4298 SSU at 100°F (930 cs.); 190.8 SSU at 210°F (41.0 cs.); pour: 5°F

Method of Manufacture: A slurry of Santocel C (10 per cent) in the mineral oil and Ucon was prepared by combining 12,000 g of the oil, 200 g of the Ucon, and 2,000 g of the Santocel in single action grease mixer. It was heated to 280°F. After 10 minutes at 280°F, 5800 g of oil was added; and the slurry was cooled to 130°F to 150°F. The resultant slurry was recycled for an average of three passes through a Manton-Gaulin laboratory homogenizer at 5000 psi and a rate of 60 pounds per hour. With homogenization, the slurry thickened. After three passes, the ASTM worked penetration leveled off at about 300, indicating a maximum state of dispersion for the processing conditions.

Grease samples were withdrawn through the Manton-Gaulin at 7500 psi as the final processing. After the grease with 10 per cent Santocel was withdrawn, additional oil was added to lower the Santocel concentration to 8 per cent. Appropriate samples of grease were processed through the homogenizer, and the procedure was repeated to make the complete line of greases with decreasing concentrations of Santocel C.

The other was silica gel grease with various concentrations of silica gel, and was prepared by the California Research Corp. Table I summarizes the composition of the silica gel greases, and the method of manufacture is indicated below the table.

III. Experimental Results

The experimental results obtained for the lime soap grease and the 10 per cent silica gel grease are shown in Figures 2 and 3, respectively. In Figure 2(A), the upward and downward arrows represent the curve obtained while $\dot{s}$ was increased (upcurve) or decreased (downcurve); the numbers on the hysteresis loops represent the order of experiments performed. Thus, one sees that the first experiment (No. 1) gives the largest loop, and that the size of the hysteresis loop decreases with successive experiments, reaching a reproducible curve with no loop. The results for the silica gel grease also show similar behavior (Figure 3).

Experiments were performed with the lime soap grease diluted with High Vacuum Oil in various proportions. It was found that the sample diluted in the ratio 1:0.18 of lime soap grease to High Vacuum Oil shows a hysteresis loop which is destroyed with repeated cycles, eventually reaching a reproducible flow curve without a loop as in the case mentioned above, whereas the more dilute samples present no loop even in the first cycle. In Figure 4 are shown the experimental results obtained for the lime soap grease diluted with High Vacuum Oil in various proportions. (The proportions are shown in the ratio of grease to High Vacuum Oil). The flow curves for the samples with 1:0 and 1:0.184 are the reproducible nonhysteretic curves obtained after repeated cycling.

Similar results were also obtained for the silica gel greases. That is, 10 and 8 per cent silica gel greases show hysteresis loops destroyed by repeated shearing, while the samples below 8 per cent exhibit reproducible nonhysteretic curves. Figure 5 represents the results obtained for the silica gel greases with various concentrations of silica gel; the curves for the 8 and 10 per cent greases are the reproducible nonhysteretic ones.

With the silica gel greases which present reproduc-

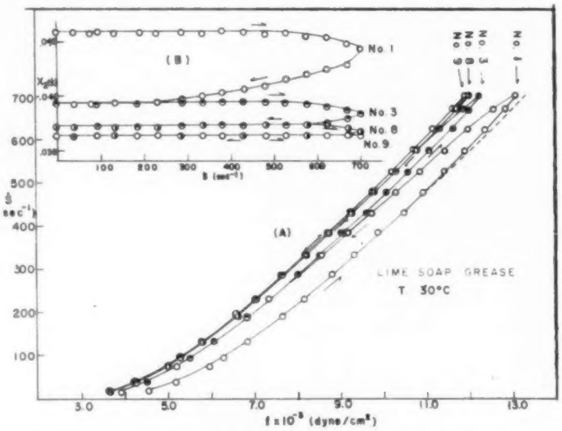

FIGURE 2—(A) Thixotropic flow curves of lime soap grease in repeated experiments at 30°C. (B) The decay curve of X_2 against the rate of shear.

ible nonhysteretic curves, stress-relaxation experiment was performed, i.e., the shear stress was measured while the shear rate was kept at a certain value; no change was found for any samples irrespective of thickener concentrations. That is, the shearing ceases its destruction of structure in the samples.

The silica gel (Santocel C), which was used as thickener in the silica gel grease, was examined by an electron microscope. The gel is an assembly of porous granular aggregates, each of which is about 1μ in diameter, composed of an aggregation of small SiO_2 corpuscles of about 100 Å diameter (cf. Figure 6). Figure 6 was obtained for the dry sample spread on a collodion membrane without metallic shadow.

IV. Discussion of the Experimental Results

(1) *Model for the Thixotropy and the Flow Equation.*

In the above, we found that the lime soap grease and the silica gel grease exhibit thixotropy. We first

consider the model for the thixotropy of the silica gel grease.

(i) The grease is a colloidal system of silica gel particles of about 1 μ or less in diameter dispersed in oil. Since the particle is porous, the oil penetrates into the porous portion, rendering the particle somewhat flexible. This is a very reasonable assumption if one considers the results of the electron micrographical study of the silica gel (Figure 6).

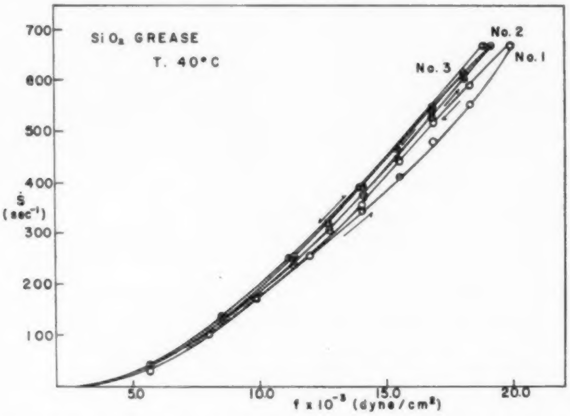

FIGURE 3—Thixotropic flow curves of silica gel grease (10%) in repeated measurements at 40°C.

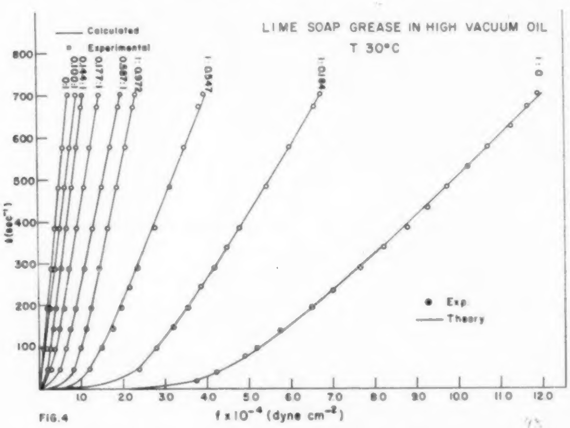

FIGURE 4—Flow curves at 30°C of the lime soap grease diluted in High Vacuum Oil in various mixing ratios. Proportion on the curve is the ratio of the grease to the High Vacuum Oil. Full curve, calculated; circle, experiment.

(ii) There are two types of dispersed particles; type 1 is completely separated from the surrounding particles while type 2 is an extended form making some bonds with neighbors. Figure 7 is a schematic representation of the two types.

(iii) In flow, type 1 acts as a Newtonian unit, and type 2 as a non-Newtonian one.

(iv) Between the two types, there exists an equilibrium, i.e, type 2 $\rightleftarrows$ type 1.

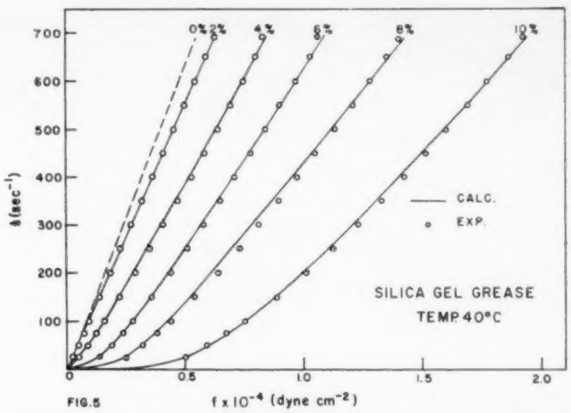

FIGURE 5—Flow curves of the silica gel greases of various concentrations of SiO_2 at 40°C. The concentration is the weight percentage. The full curves are calculated from equation (7) by using the parametric values shown in Figure 9 (A). Circles, experiment.

(v) In a flow system, equilibrium is maintained if $\dot{s}$ is small; otherwise it shifts to the right, i.e., type 2 transforms to type 1 if $\dot{s}$ is very large. Thus a structural change occurs, which recovers when the stress is released only after a prolonged elapsed time.

The model for the thixotropy of the lime soap grease is similar to the above. Here, an entangled soap fiber (submicron size) acts as type 2, whereas a non-entangled coiled fibrous soap acts as type 1.

The above models of thixotropy are essentially the same assumed by Hahn, Ree, and Eyring.[6] These authors introduced the idea of the transition, type 2 $\rightleftarrows$ type 1, into the flow equation:[7]

$$f = X_1 \frac{\beta_1}{\alpha_1}\,\dot{s} + \frac{X_2}{\alpha_2}\,\sinh^{-1}\beta_2\,\dot{s} \tag{1}$$

Here, X_i ($i = 1, 2$) is the fraction of the area on a shear surface occupied the ith type ($X_1 + X_2 = 1$);

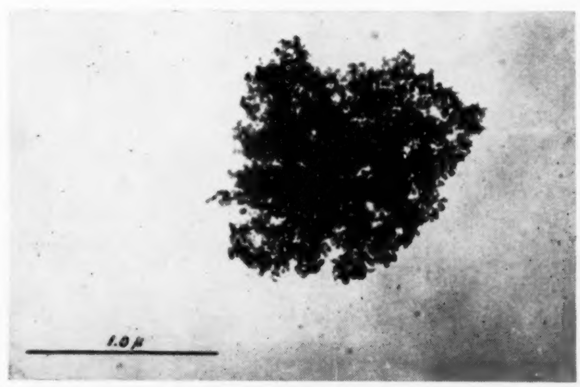

FIGURE 6—Electron-micrograph of Santocel C (silica gel). The silica gel is an assembly of granules, one of which is shown in this figure.

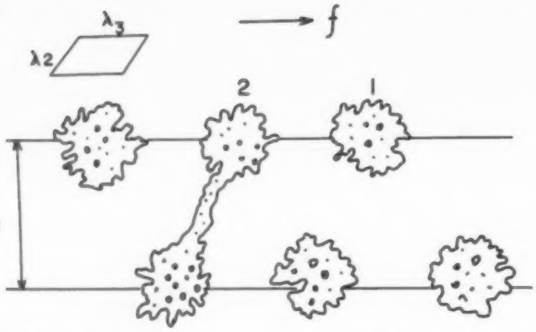

FIGURE 7—Schematic representation of flow units in the silica gel grease. 1: Newtonian unit; 2: non-Newtonian unit. Oil molecules, which fill the whole space not occupied by the silica gel units, are not shown.

β_i and $1/\alpha_i$ are the molecular parameters which are proportional to the relaxation time and the shear modulus (or intrinsic shear stress) of the ith type, respectively.

The rate of transition, $2 \rightarrow 1$, is given by the following equation:[6,8]

$$-\frac{dX_2}{dt} = k_f X_2 e^{\mu\omega/kT} - k_b(1-X_2) e^{-(1-\mu)\omega'/kT} \tag{2}$$

Here, k_f and k_b are the specific rates for the forward and backward reactions, respectively, ω and ω' are the strain energies stored on unit 2 and unit 1, both the ω and ω' being functions of $\dot{s}$; and μ is a fractional number. The free-energy profile for the transition reaction is shown in Figure 8, where it is seen that the strain energy ω favors the forward reaction, while ω' hinders the backward reaction, as represented in equation (2). For the derivation of (2), reference is made to the literature.[9]

Since in our experiment the shear rate, $\dot{s}$, is uniformly increased or decreased with time at a given rate, ρ, the rate of shear is given by $\dot{s} = \rho t$, ρ being a well determined constant. Introducing the relation $\dot{s} = \rho t$, into equation (2), one obtains the solution of the latter as[8]

$$X_2 = \exp(-k_f\gamma I - k_b\gamma I')\left[X_2^{(0)} + \int_0^y k_b \gamma e^{-\frac{(1-\mu)\omega'}{kT}} \times \exp(k_f\gamma I + k_b\gamma I')\,dy\right] \tag{3}$$

where $X_2^{(0)}$ is the value of X_2 at zero time, and I, I′, y and γ are defined as follows:

$$I = \int_0^y e^{\mu\omega/kT}\,dy$$

$$I' = \int_0^y e^{-(1-\mu)\omega'/kT}\,dy$$

$$y = \dot{s}/\gamma\rho$$

$$\gamma = (kT/c\rho^2)^{1/3}$$

According to the Hahn-Ree-Eyring theory,[6] the c in the last equation is a constant in the relation, $\omega = c\,\dot{s}^2$.

When y is very small (i.e., $\dot{s}$ is very small or $\gamma\rho$ is very large), equation (3) tends to the following equation:

$$X_2 = \frac{k_b}{k_f + k_b} + \left(X_2^{(0)} - \frac{k_b}{k_f + k_b}\right)\exp(-k_f - k_b)\frac{\dot{s}}{\rho} \tag{4}$$

where the approximation, $I \simeq y$, has been made. If the system is in a thermal equilibrium state at $t = 0$, one obtains from equation (2) the initial thermal equilibrium value, $X_{2e}^{(0)}$, which is given by

$$X_{2e}^{(0)} = k_b / (k_f + k_b) \tag{5}$$

where the following conditions have been introduced: $-dX_2/dt = 0$ and $\dot{s} = 0$ at $t = 0$.

As one may see from the experiments mentioned above, the initial state of the system in Experiments 2, 3, . . . is not in a thermal equilibrium when $\dot{s} = 0$, i.e., $X_2^{(0)} \neq X_{2e}^{(0)}$. Here the $X_2^{(0)}$ indicates the initial value of X_2 when the system is not in a thermal equilibrium. Since $X_2 \simeq X_2^{(0)}$ over the range of small $\dot{s}$ (cf. equation (4)), one obtains from (1) the following approximate flow equation for this range:

$$f = (1 - X_2^{(0)})\frac{\beta_1}{\alpha_1}\dot{s} + \frac{X_2^{(0)}}{\alpha_2}\sinh^{-1}\beta_2\dot{s} \tag{6}$$

For a reproducible non-hysteretic curve, the flow equation is given by[7]

$$f = (1 - X_2^{(r)})\frac{\beta_1}{\alpha_1}\dot{s} + \frac{X_2^{(r)}}{\alpha_2}\sinh^{-1}\beta_2\dot{s} \tag{7}$$

where $X_2^{(r)}$ expresses the X_2 in reproducible and reversible flow systems, and it is constant.

By applying equations (6) and (7) to the appro-

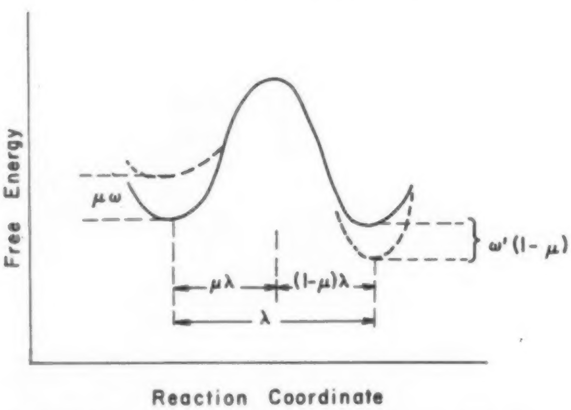

FIGURE 8—Free energy profile for the transition, non-Newtonian→Newtonian.

priate cases, one can easily determine the parametric values of β_1/α_1, α_2, $X_2^{(o)}$, $X_2^{(r)}$, and β_2. Thus, $X_2(\dot{s})$ is calculated fom the following equation which is obtained from equation (1):

$$X_2(\dot{s}) = \frac{f-(\beta_1/\alpha_1)\dot{s}}{(1/\alpha_2)\sinh^{-1}\beta_2\dot{s}-(\beta_1/\alpha_1)\dot{s}} \tag{8}$$

(2) *Lime Soap Greases*

The values of X_2 for the lime soap grease, which were calculated from (8) using the flow data shown in Figure 2 (A), are plotted against $\dot{s}$ in Figure 2 (B). One sees that X_2 decreases not only in upcurves, but also in downcurves, i.e., that the recovery (the backward reaction) is very slow. Finally, in Experiment 9, X_2 reaches a constant value (a horizontal line).*

The flow data shown in Figure 4 were analyzed by applying equation (7), and the parametric values of $X_1\beta_1/\alpha_1$, X_2/α_2, and β_2 were obtained, which are shown in Figure 9 (B). The full curves in Figure 4 were calculated from (7) by using the parametric values shown in Figure 9 (B). One sees that equation (7) applies very well for this case.

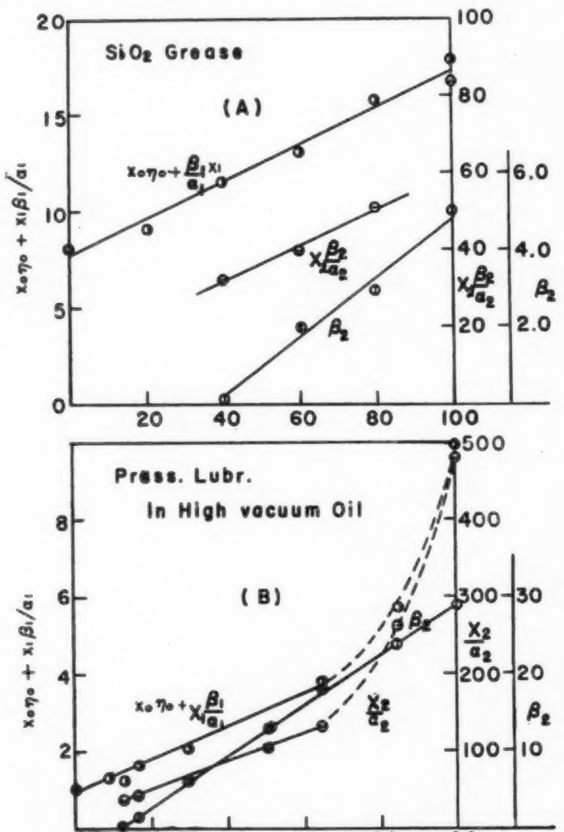

FIGURE 9—(A) The parametric values of the silica gel grease against the SiO_2 concentration (wt. %). (B) The parametric values of the lime soap grease in High Vacuum Oil against the grease concentration (wt. %) in the mixture.

* For calculating Figure 2 (B) from equation (8), the following values were used: $\beta_1/\alpha_1=9.95$, $1/\alpha_2=13580$, and $\beta_2=29$.

In Figure 9 (B), one sees that β_2 increases linearly with the concentration of the lime soap grease in High Vacuum Oil. This seems interesting since in dilute solutions β_2 is usually independent of concentration.[7, 10] The values of $X_1\beta_1/\alpha_1$ and X_2/α_2 increase with concentration, linearly at low concentrations, but abruptly above 70 per cent, as expected. It is worthy of note that thixotropy appears above 70 per cent. This is due to the fact that the entanglement of soap molecules occurs markedly above this concentration.

In the Hahn-Ree-Eyring theory of thixotropy,[6] the term of the backward reaction was neglected. This approximation cannot be applied in the present case, because, if it is true, X_2 must reach zero after repeated cyclic shearing, in contrast to the fact shown in Figure 2 (B). Thus, it is very necessary to introduce into (1) equation (3), where the backward reaction has been considered. As a result, the calculation of the thixotropy loops becomes very complicated. But, to a good approximation, one may assume $\omega' = 0$ in equation (3). Then, the calculation of the course of the thixotropy curves can be made reasonably easily.[8] The detailed description of the calculation and the results found will be given elsewhere.

(3) *Silica Gel Grease*

We[10] showed theoretically elsewhere that the Newtonian unit in equation (1) is sphere-like. This conclusion was reached by the following steps. (1) The viscosity, η, for non-Newtonian solution systems is given by[7]

$$\eta = X_0\eta_0 + X_1\frac{\beta_1}{\alpha_1} + X_2\frac{\beta_2}{\alpha_2}\frac{\sinh^{-1}\beta_2\dot{s}}{\beta_2\dot{s}} \tag{9}$$

Here the subscript zero represents the solvent; η_0, which equals β_0/α_0, is the viscosity of the solvent, and $(\sinh^{-1}\beta_2\dot{s})/\beta_2\dot{s} \simeq 1$, if $\dot{s}$ is very small. (2) The contribution due to the Newtonian units (the sum of the first and the second terms on the right hand side of equation (9)) is easily calculated by analyzing the flow curve corresponding to equation (9). (3) By subtracting η_0 from the sum, the term, $X_1\beta_1/\alpha_1$, is obtained, where $X_0 \simeq 1$ has been assumed. (4) By dividing $X_1\beta_1/\alpha_1$ by $\phi\eta_0$ (ϕ = volume concentration), one obtains the intrinsic viscosity, $[\eta]$, for the Newtonian unit 1, where it has been assumed that $\phi \simeq X_1$. (5) If the $[\eta]$ for unit 1 equals 2.5, then it is concluded that the Newtonian unit approximates spherical form.

The parametric values, which were obtained by analyzing the flow curves for the silica gel grease (Figure 5), are plotted against concentration (Wt. %) in Figure 9 (A). Using the Newtonian viscosity ($X_0\eta_0 + X_1\beta_1/\alpha_1$) for the silica gel grease, the intrinsic viscosity is calculated as mentioned above; the results are

summarized in Table II. Here ϕ is given by (C/ρ) $\{C/\rho)+(100-C)/\rho_0\}$, C, ρ and ρ_0 being the concentration in weight per cent, the density of the silica gel and that of the solvent, respectively. Column 5 gives the $[\eta]$ calculated by using the true density (2.3) of SiO_2, whereas in column 6 the apparent density, 0.48, was used, which was obtained by the authors using heavy mineral oil as the liquid in the measurement of the density. The apparent density, 0.48, corresponds to the porosity P of 79 per cent, P being equal to 100 $\times$ hole volume/actual volume.

The last column of Table II indicates that the $[\eta]$ approaches 2.5, in low concentrations; this is natural if one considers the assumptions included in the calculations. It is noteworthy that the results using the apparent density are better than those obtained using the true density. This point could be explained as follows: In the silica gel grease, the oil penetrates into the holes, but does not occupy the holes completely (cf. the porosity); the silica gel particle with the entrapped oil molecules behaves as a flow unit, i.e., the entrapped oil molecules do not flow independently, but behave as though they were a part of the aggregate. Thus, the apparent density seems to yield better results.

In connection with the above results, the studies of Mardles and Puddington[11] on the intrinsic viscosities of kaolin in various solvents are very interesting. Here it was known that kaolin disperses in a spherical form

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TABLE II

Einstein Coefficient of Newtonian Unit of Silica Gel Grease

Conc. Wt. %	$X_0 \frac{\beta_0}{\alpha_0}$ (poise)	$X_0 \frac{\beta_0}{\alpha_0} + X_1 \frac{\beta_1}{\alpha_1}$ (poise)	$(\eta_{sp})_1$	$[\eta]$ $(\rho = 2.3)$	$[\eta]$ $(\rho = 0.48)$
0	8.1				
20		9.2	0.133	17.5	3.2
40		11.5	0.420	26.9	6.0
60		13.0	0.605	25.7	5.8
80		15.8	0.951	29.7	7.0
100		17.5	1.160	28.9	6.1

in the solvents. According to these authors, the $[\eta]$ values are much larger than 2.5, for example, $[\eta] = 51$ in light mineral oil. It was also found by the authors that generally the solvent with better wettability for kaolin presents smaller $[\eta]$. In the calculation of $[\eta]$, however, the authors used the true density of kaolin. A solvent with good wettability can penetrate into the holes almost completely; therefore, its density approaches the true density; as a result, in this case, the $[\eta]$ calculated by using the true density approaches 2.5. For the systems with high $[\eta]$, i.e., kaolin in solvents with poor wettabilities, however, the apparent density should be used, then the $[\eta]$ will approach 2.5.

V. Summary

The flow curves of lime soap grease and silica gel grease were determined by a rotational viscometer. For both greases, a large hysteresis loop was obtained in a first cyclic shearing, the size of which decreased with repeated experiments, and finally a reversible and reproducible flow curve was obtained. The final flow curve was still non-Newtonian. This trend was quite different from the case of aqueous bentonite suspension,[8] where a reproducible hysteresis loop was finally obtained.

A general equation for thixotropy was derived from the viewpoint of the theory of rate processes, here thixotropy was assumed to be brought about by the transition, non-Newtonian unit → Newtonian unit. The concentration of the non-Newtonian units in the lime soap grease was calculated as a function of $\dot{s}$, the rate of shear. It was found that the concentration decreases successively in the upcurve as well as in the downcurve stages, finally reaching a constant value by repeated cyclic shearing.

The reproducible flow curves obtained for the silica gel greases with different concentrations of silica gel were analyzed by using the Ree-Eyring equation. The intrinsic viscosity for the Newtonian unit was calculated from their parametric values of the Newtonian unit; it approached to the Einstein coefficient, 2.5, when the apparent density of the silica gel was used. From this result, it was concluded that the Newtonian unit of the silica gel grease is an approximately spherical aggregate of the primary particles of silica (100A) with the oil molecules entrapped in the pores of the aggregate.

Acknowledgments

We wish to thank the California Research Corp. for the silica gel grease which was specially prepared for the present study, and also the Utah Oil Refining Co. for the lime soap grease which was given to us with various other kinds of greases. This work was supported by the National Science Foundation Fund and also by the Petroleum Research Fund administered by the American Chemical Society. Grateful acknowledgments are hereby made to the donors. One of the authors (Kim) expresses his appreciation to the National Lubricating Grease Institute for the fellowship granted to him. Our cordial thanks are also due to Dr. Uchizono of the Department of Physiology, University of Utah, for the electron micrograph of silica gel which was taken by him.

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Presented at the NLGI 28th annual meeting in Chicago, October, 1960

Future Package Trends And Designs for Lubricating Greases

By: F. W. Langner, Socony Mobil Oil Co., Inc.

A NATURAL question for every manufacturer of greases and heavy lubricants is, "What is the trend in package designs and what is being done to bring down or keep the cost of grease packages from rising?"

As for the designs of the three most commonly used grease packages, i.e. the 400-pound, 120-pound and 35-pound fully removable head drums and pails, there is a very strong feeling at this time that the overall sizes should not be changed. However, much work has been carried on and surely further developments will be made to reduce the weight and increase the strength of the lighter weight containers.

The initial work of standardizing the sizes and construction of grease packages was completed in 1954. Possibly the adoption of the standard, 120-pound, fully removable head drum was one of the most important items of the standardization work. It permitted the manufacturers of the dispensing equipment to reduce the types and sizes of their equipment to a minimum number of lines.

Another great improvement resulting from the standardization of the 120-pound, fully removable head drum and the 35-pound, lug cover grease pail was that

Lighter Weight and Cheaper Packages

Item No.	*Size*	*Construction*	*Weight (In Pounds)* *Tare*	*Diff.*	*% Diff.*	*Cost $*	*Cost Diff.*	*% Diff.*
1	55 Gallon Tight Head Drum	18 gauge	48.5	—		6.19		
		20/18 gauge	39.0	9.5	−19.6	6.69	.50	− 8.1
2	400 pound F.R. Head Drum	18 gauge	51	—		6.84		
		20/18 gauge	43	8.0	−15.7	6.34	.50	− 7.32
3	120 pound F.R. Head Drum	20 gauge	16	—	—	2.81	—	—
		22 gauge	13	3	−19	2.68	.13	− 4.62
		24 gauge	11	5	−31	2.52	.29	−10.6
		26 gauge	7	9	−56	2.29 to 2.39	.52 to .42	−18.5 to −14.9
		Fiber	8	8	−50	1.82	.99	−35.2
4	5 Gallon/ 35 pound L.C. Pail	24 gauge	5.0	—	—	1.08	—	
		26 gauge	4.0	1.00	−20	.959	.122	−11.1
		28 gauge	3.75	1.25	−25	.923	.157	−14.4
		29 gauge	3.25	1.75	−35	.81	.27	−24.8

1 Color on Base Coating Included (Cost=$.14/Pkg.)

Note: Cost Data—Published Prices—Eastern Part of United States. Prices will vary in other sections.

FIGURE 1.

it made possible the use of automatic filling and crimping machines. Anyone who remembers the pre-standard era will recall that different crimping tools were required for nearly every drum and pail from various suppliers.

Standardization work and new developments are possible only through the cooperative efforts of the Petroleum Packaging Committee of the Packaging Institute, the API-NLGI Joint Container Committee, the Manufacturing Chemists Association, the Steel Shipping Container Institute, military and governmental agencies, the American Standards Association and other industries.

First, I would like to take up the 55-gallon, tight head drum. The construction of this drum is standard almost all over the world at this time. As the result of work done several years ago, the cost of this drum has been reduced, and it is now permissible to use 55-gallon drums having 20-gauge bodies and 18-gauge top and bottom heads. The use of the 20/18-gauge drum is increasing very rapidly. The U. S. Department of Commerce says that in the first nine months of 1958 a total of 361,538 drums of 20/18-gauge construction were manufactured and for the first nine months of 1959, 1,110,703 drums were manufactured. This represents an increase of more than 200 per cent.

In the case of the 400-pound, fully removable head drum, which is normally used for grease and heavy lubricants, data are not available on the number of 20/18-gauge drums used, but there is no reason why this drum is not satisfactory for greases and heavy lubricants. Extensive use is being made of the drum of the lighter construction. It follows that for liquids, the freight classification rules still have to be changed so as to permit use of the 20/18-gauge, fully removable head drum.

For the 120-pound, fully removable head drum, the changes have been quite extensive. Originally the standard for this size called for 20-gauge only. We feel that today the 22-gauge drum has almost completely supplanted the use of the 20-gauge construction.

Figure 1 shows comparisons of weight and cost of different types of construction for the three sizes I have already mentioned. It also gives comparison for the 5-gallon/35-pound lug cover pail. Here, too, we believe that in the future a lighter gauge pail, with some modification in its construction, will replace the 26-gauge.

It is of real interest to see the kind of work that was carried on through the cooperative action of the different organizations that have been mentioned, in testing the lighter gauge or new construction of the different packages. For this reason, we are showing two illustrations of the different types of construction of a 55-gallon drum that was tested with the 18-gauge drum as the standard of comparison. Then a test was

Test No.	Avg. Rockwell "B" Hardness	Avg. Tare Wt. Lbs.	Type Failure See Note (1): Triangular	Vertical	Vacuum At Failure In. of Hg. (Avg.)	Performance Rating	Location of Rolling Hoops & Corrugations
1	Standard 55-Gal., 18 Ga., ICC-17E Drum						27/64" Rolling Hoops
	50	49	None		29" No Failure	Control Drums	
2	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						27/64" Rolling Hoops
	54	40	Triangular	-	14.0"	10	
2(a)	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						27/64" Rolling Hoops
	54	40	Triangular	-	15.1"	8	
2(b)	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						27/64" Rolling Hoops
	51	40	Triangular		16.5"	6	
3	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						5/8" Rolling Hoops
	51	40	Triangular	Vertical	24.3"	3	Same as Test No. 2
4	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						27/64" Rolling Hoops
	Not Avail.	41	Triangular		19.3"	5	Same as Test No. 2, but 7 corrugations added in top and bottom panels. See Detail Note No. 4

Test No.	Avg. Rockwell "B" Hardness	Avg. Tare Wt. Lbs.	Type Failure See Note (1): Triangular	Vertical	Vacuum at Failure In. of Hg. (Avg.)	Performance Rating	Location of Rolling Hoops & Corrugations
4(a)	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						27/64" Rolling Hoops
	56	40	Triangular	-	20.7"	4	Same as Test No. 2, but 7 beads added in top and bottom panels. See Detail Note No. 5.
5	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						3-27/64" Rolling Hoops
	58	40		2-Vertical	3-29" No Failure 2-27.8" Failed	1	
5(a)	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						3-27/64" Rolling Hoops
	57	40	Triangular	Vertical	26"	2	
5(b)	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						1-27/64" Rolling Hoop
	Not Avail.	40.5	Triangular	-	14.3"	9	
5(c)	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						4-27/64" Rolling Hoops
	Not Avail.	41	-	3-Vertical	2-29" No Failure 3-28.2" Failed	1X	
6	55-Gal., 20 Ga. Body - 18 Ga. Heads, ICC-17E						2-27/64" Rolling Hoops
	Not Avail.	40	Triangular	-	15.6"	7	Same as Test No. 2, except body made of "Quarter Hard Steel".

FIGURES 2 and 3—Vacuum collapsing test on 55-gal., 20/18-gauge, tight-head drums, April 24, 1959, U. S. Steel Products, Camden, N. J.

made on 55-gallon, 20/18-gauge drums with the rolling hoops and corrugations arranged as shown in Figures 2 and 3. Out of these tests, we learned that one could even make improvements in the shape of the corrugations for, as shown in Figure 4, the old style corrugations were shaped like a sine wave and the new type corrugations are made similar to beads on a 5-gallon lug cover pail. The comparison of the increased strength

due to the change of location of the rolling hoops and the use of corrugations is shown in the chart in Figure 5.

It is apparent that by modifying the design slightly, the resistance of the 20/18-gauge drum to collapsing under vacuum conditions is greatly increased. For example, if the performance rating of 1 and 5 are com-

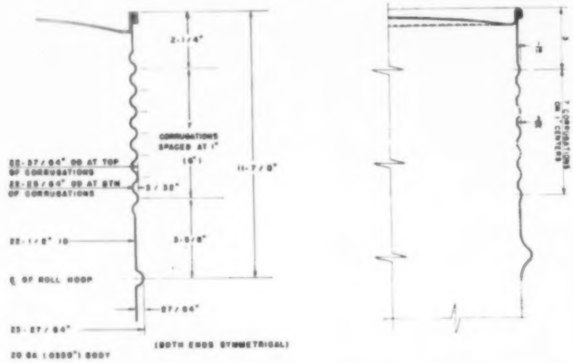


FIGURE 4—Vacuum collapsing test on 55-gal., 20/18-gauge tight-head drums. Detail of corrugations.

NOTES: (1) When drums failed, the failure was either triangular in shape, the sidewalls crushed toward a vertical center axis in a rough triangular shape. Other failures were of a vertical nature in that crushing resulted in the height of the drum being reduced and the sidewalls assuming roughly an accordion configuration. (2) Gauge reading indicates reading of gauge which was located at some distance from the drum. A correlation of this gauge reading versus actual vacuum in the drum was taken, and indications are that the differential resulted from time lag due to constriction of piping between drum and gauge. Using this correlation, a graph was prepared to arrive at a corrected gauge. It should be noted that average pump down-time to either failure or 29 inches was two to three minutes. (3) For all tests, except 5 (b), four drums with 25 gallons of water were tested, and the fifth was empty in each case. There was no major difference in the results with the drums partially filled or when empty. (4) Left, detail of corrugations (sine wave type). (5) Right, detail of bead type corrugations.

bined, i.e. adding a third rolling hoop between the two normal hoops, and then adding seven beads in the upper and lower section of the drum, we obtain a drum that has a strength, for withstanding vacuum and shipping, comparable to that of the 55-gallon, 18-gauge drum. The type of construction that is described can presently be obtained from nearly any drum manufacturer without the use of new tools. However, it has been found that the 20/18-gauge drum with only the additional corrugations in the upper and lower section is completely satisfactory for almost all, except extreme conditions.

We would like to show also how tests were made on the 5-gallon lug cover pail to determine how a light gauge pail can have approximately the same strength as the ones that are made of 24-gauge. In these tests the standard of comparison was the 24-gauge pail. Figure 6 shows the set-up that was used to make comparative tests as to the collapsing strength of pails made

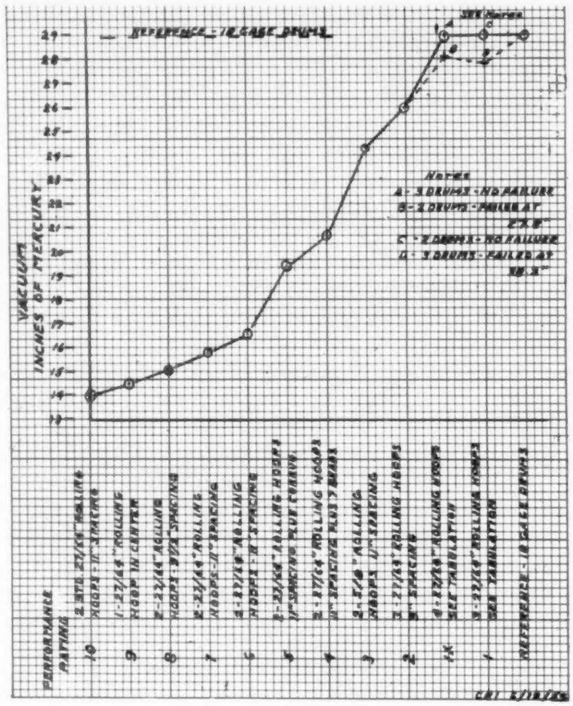


FIGURE 5—Vacuum collapsing tests on 55-gal., 20/18-gauge tight-head drums at U. S. Steel Products, Camden, N. J., April 24, 1959.

of different construction. The upper picture in Figure 6 shows that we tested 54 pails, 18 of which were different types of construction from three different manufacturers. The test equipment that was used is quite simple. It consisted of a normal laboratory vacuum pump and a vacuum gauge. The use of a vacuum pump for comparative testing of packages is an interesting development. The adaptation of a vacuum pump for testing was first tried out in one of our grease manufacturing plants that had reported trouble with 35-pound, 26-gauge lug cover pails collapsing when the hot grease cooled in a pail that had been closed immediately after filling. Pails on which the covers were equipped with ¾ inch drum flanges were filled with hot grease. The cover was crimped on immediately and a valve applied to the ¾ inch opening. Vacuum readings were taken over a period of 20 hours. The maximum reading of vacuum that was obtained was 4.5 inches of mercury. We had previously made an elaborate set-up to determine the vacuum conditions that caused the collapse of 35-pound, 26-gauge lug cover pails, but this did not duplicate the extreme conditions. It was decided to use a laboratory type vacuum pump on the pails. The results were obtained very quickly, and amazingly are comparable from one test to another one.

The tests on the 55-gallon drum were made with a larger type vacuum pump. When a 55-gallon drum

A. Shows 21 pails each from J&L, Ohio and Inland; also equipment used for testing pails. Pump could draw up to 28" of Hg vacuum.

B. J&L 26-gauge pails. All were tested. Compare results with Figures 5 and 8.

C. J&L 28/26-gauge pails. All were tested. Compare results with Figures 6 and 9.

D. J&L 28-gauge pails. Three pails were not tested. Compare results with Figures 7 and 10.

FIGURE 6—Note 1: Pails marked N.T. were Not Tested. Note 2: In each case, test was halted when pail collapsed. Consequently, the strongest pails were subjected to the highest vacuum. Thus when they collapsed, they were badly deformed. It is emphasized that any pail which withstood approximately 20" of vacuum could withstand all normal filling and shipping damage.

collapses, incidentally, it makes a noise comparable to a small field gun.

Now back to the testing of pails. In every case the pails were tested to destruction and for this reason, some of the pails that showed the most severe dents are the ones that withstood the highest vacuum. The final data of these tests are shown in Figure 7 and it is rather amazing to find that a pail constructed of 28-gauge throughout withstood a higher vacuum for any location of the beads than a pail made of 28-gauge body and 26-gauge top and bottom.

It follows that in all changes of specification, it is very important to consider also the problems that would be encountered by the pail manufacturer. For this reason the location of the reinforcing beads was selected as a compromise at 3¼ inches from the top and bottom of the pail. Again, it follows that two beads normally are not required and only the upper bead would be recommended.

After the tests that are shown in Figures 6 and 7 were made, a most interesting development became possible. We believe that the marring of the decoration in the shipping of the lug cover pail is quite common. Considerable tests and developments were made in connection with trying to improve the shipping qualities of the lug cover pail and it was found that in many instances the damage to the appearance of the pail was caused by the wire handle and the wooden grip. Quite

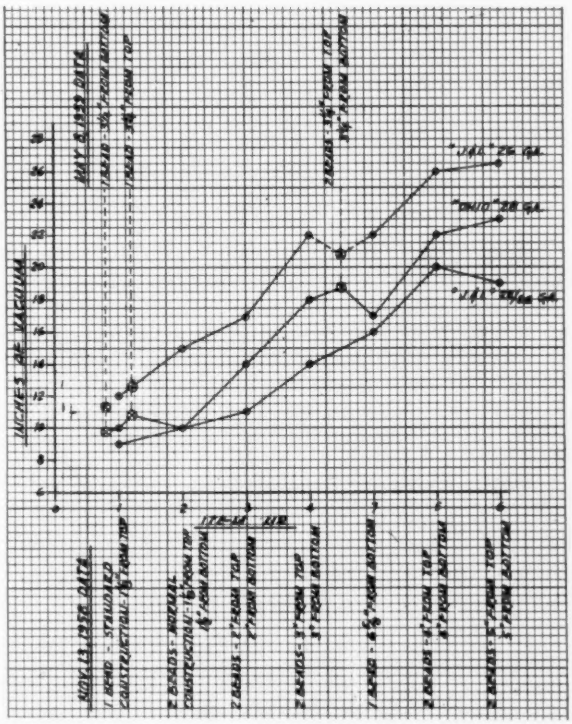


FIGURE 7—Vacuum tests on 5-gal. lug cover pails, at J&L plant, Bayonne, N. J., Nov. 13, 1958 and data from Ohio Corrugating tests, May 8, 1959.

recently the development of a plastic grip has made a decided reduction in the damage that one pail would cause to an adjacent pail in shipping, but the wire handle itself still continued to damage the adjacent pail. We would like to show you how damage occurs from the handles in Figure 8, where Picture 1 shows the contact of the wire handle with the adjacent pail and Picture 3 shows how the wooden grip also contacted the adjacent pail. Picture 2 shows the use of a new design of wire handle and Picture 4 shows the effect of using a smaller diameter plastic grip.

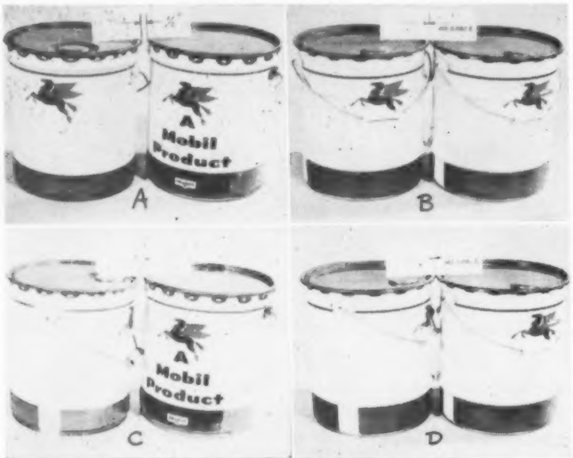


FIGURE 8—A. Pails with wire handles presently used. Two points of contact for each handle. Each point mars lithography. B. Pails with new design handles. Light contact only on top of bead. Lithography not marred by handle. C. Pails with presently-used wood grip. Two points of contact. Each point mars lithography. D. Pails with properly-designed plastic grips. No contact with adjacent pail. Lithography not marred by grips.

Figure 9 shows the comparison of the shape of the new type handle and grip compared to the former handle and grip. The discovery that was made that permits the use of the new type of handle is that, if the upper bead is relocated at 3¼ inches from the top of the pail, then it is possible to raise the ears that connect the pail handle to the pail body so that they are located at 1 7/16 inches from the top of the false wire. Having raised the ears on the pail, it is no longer necessary to have a straight section in the wire handle, and a rounded handle can be used that fits quite closely to the body of the pail. The construction of this pail and the location of the ear are shown in Figure 10.

At the NLGI Annual Meeting on October 25-28, 1959 at New Orleans, a paper was presented on bulk grease handling. This paper first was given by a representative of a large steel manufacturing organization and discussed different methods of handling grease in bulk. I wish to show you some developments that have been made during the last year. Figures 10A, 10B and 10C show developments by the American Lubricants,

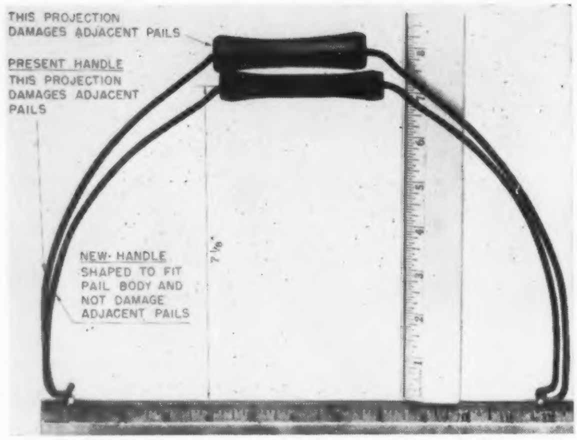


FIGURE 9.

Inc. organization in Buffalo, New York, and were made available for this paper.

Figure 10A shows a 4465-pound capacity portable tank.

Figure 10B shows a 4100-pound portable tank of a different design.

Figure 10C shows a proposed method of bulk grease transportation for delivering grease into a customer's bin.

I believe that all of these new developments are of real interest. It follows that each location and installation has different problems.

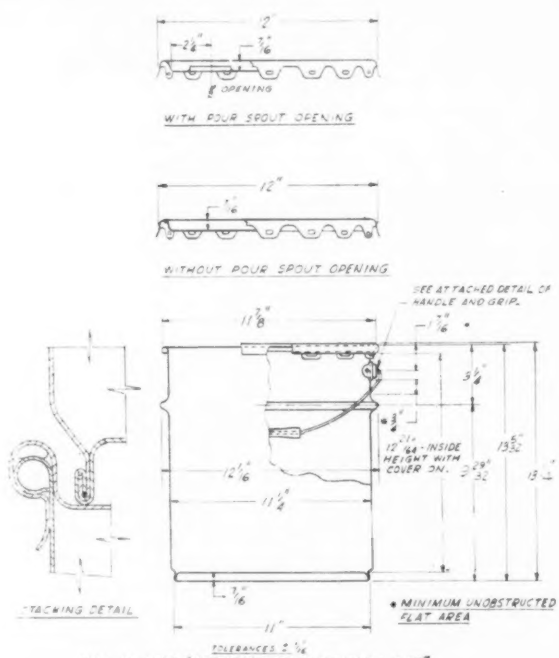


FIGURE 10—Proposed specifications, 5-gallon (35 lb.) lug cover pail (ICC-37A60, 26-gauge & ICC-37A80, 24-gauge).

I do not want to go into the pros and cons of some of the large grease bins and methods of handling that were given in the paper that was presented in October 1959 nor into the different methods that I have just shown, but I would like to present to you a modern method of handling grease in bulk. The method that

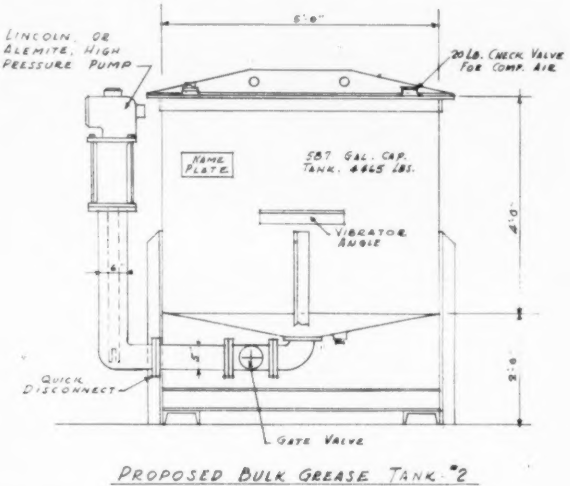


FIGURE 10A.

I shall discuss is a bulk bin that is the correct size for grease manufacturing facilities, warehousing and mechanical handling as well as for shipping by railroad and truck. Until recent times, the 400-pound drum has been the maximum grease package and this size of package could be handled by one man with a hand

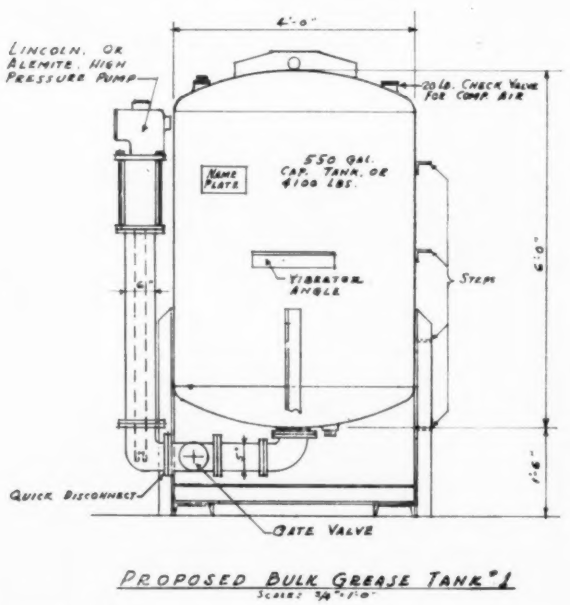


FIGURE 10B.

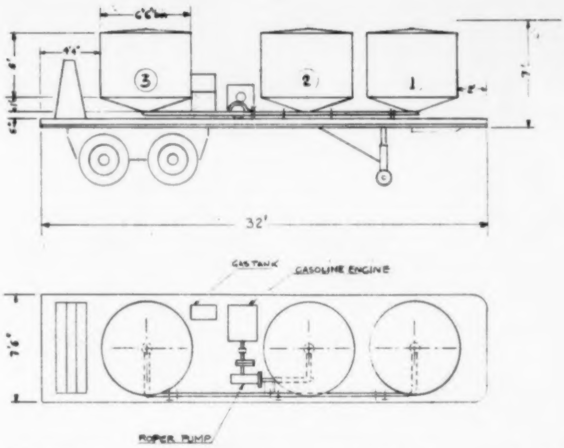


FIGURE 10C—Proposed bulk grease trailer. Average trailer dim.: width, 7′ 6″; height, 7′; length, 32′. Three bulk tanks ¼″ steel. Each, 10,000 lbs. net weight; max. 32,000 lbs. gross weight; 1 3″ Roper pump; 1 24-hp gasoline engine.

truck. The new bulk bin that I shall discuss is in the same category as a 400-pound drum for handling by means of mechanical equipment that normally is available in all grease manufacturing plants, warehouses and customers' plants. The gross weight of this bin is 4000 pounds and has a net content of 3000 pounds. The size is so arranged that it can be handled economically by over-the-road trucks or by rail cars. Let me summarize the key points that must be considered in making a desirable bulk grease container. They are as follows:

1. The container must be of such size and shape that

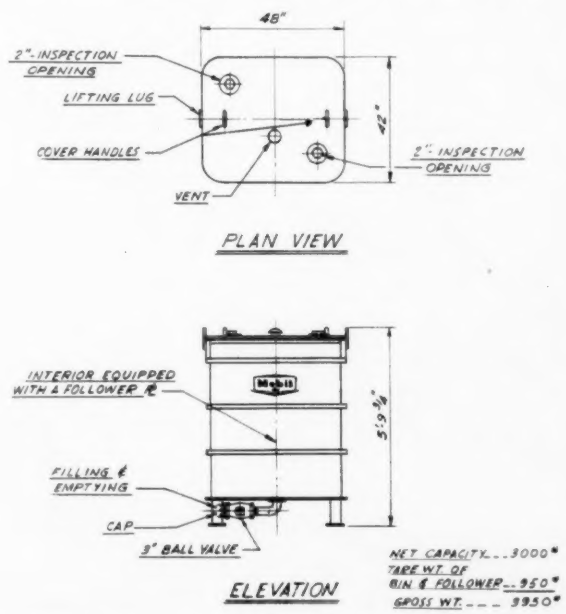


FIGURE 11—Mobil bulk bin for low penetration grease.

FIGURE 12.

it can be handled by existing fork trucks at the grease plants and marketing warehouses.

2. It must be possible to store the container in the same manner as palletized packages.

3. The container must be of such size that it can be handled economically on over-the-road trucks or in rail cars.

4. The "bulk bin" that is illustrated is designed to comply with the above three items and, in addition, is so arranged that it can be handled on special freight cars in full car-loads.

5. The container must be equipped with inspection openings so that the empty or full container can be inspected at any time.

6. The interior must be accessible so that it can be cleaned when required.

7. Product contamination with old product on the sides of the container must be minimized.

8. The container must be of such a size that it will lend itself to local distribution with the "Morhaul" type of equipment.

There are other important considerations of a bulk carrier and they are:

FIGURE 14.

FIGURE 13.

1. The cost of each bin with a follower plate.

2. Every plant that fills these bulk bins must have a 5000-pound capacity scale readily available and, if possible, at the point where the grease is filled into the bin.

3. The bin will wear out and require replacement.

4. The follower plate will require maintenance and this can well be quite expensive.

5. To change from one product to another will require cleaning of the bin.

6. Depending on the wear and tear on the bin and where it is used and warehoused, the bin may have to be repainted at regular intervals.

Figure 11 shows the bulk bin that has just been described. This bin will hold 3000 pounds of grease and have a gross weight of a little over 4000 pounds. The dimensions of 42 inches x 48 inches wide and an overall height of 6 feet permit economical shipment by over-the-road truck or by rail cars.

Figures 12 and 13 show actual pictures of bulk bins that have recently been put into use and are performing

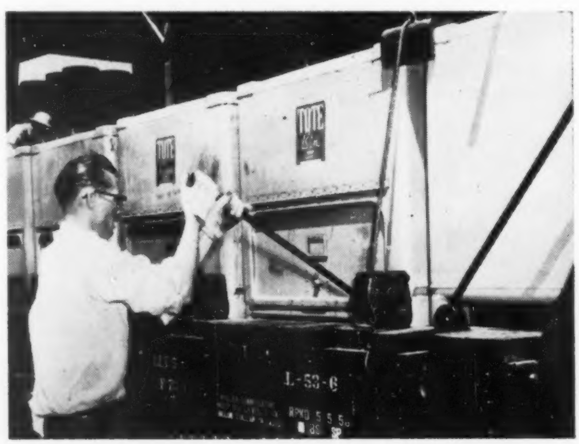


FIGURE 15.

very well. These bulk bins with the follower plate removed can be used to handle bulk fluid lubricants. The bulk bins that are illustrated by the two figures are made of steel. We have contacts with two concerns that are interested in developing plastic or plastic and metal combination bins that have a much lower tare weight.

Figures 14 and 15 are shown as a matter of interest. These bins are full of dry chemicals and are presently being shipped on flat cars that are equipped with plates for anchoring the legs. As shown in Figure 15, after they are placed on the flat car, they are fastened in place by means of a simple winch. These last two pictures are shown to illustrate that the chemical industry already has worked out a system of distribution by rail of these bulk bins that are called "Tote Bins."

As my subject is "Future Package Trends and Designs for Lubricating Greases," I would like to take this opportunity to show two developments that may have future applications.

Figure 16 shows a proposed bin made of fiberglass. This bin weighs approximately half that of a steel bulk bin. Plastic bins presently are being produced, but not for grease at this time, by Space Structures, Inc., which was kind enough to permit the use of this drawing.

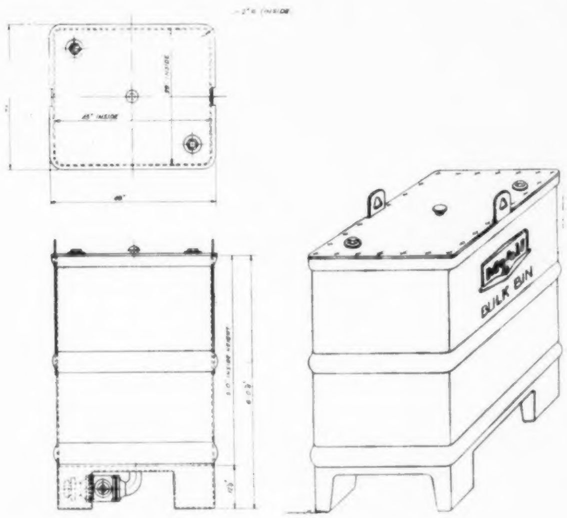


FIGURE 16.

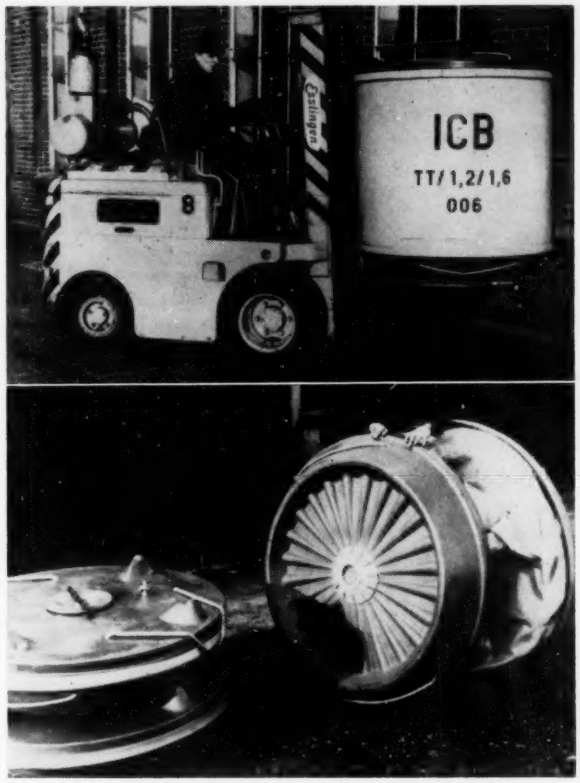
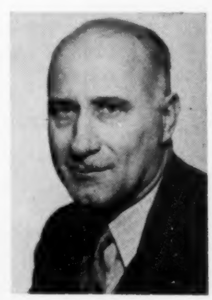


FIGURE 17—Top: transport of the loaded TT-container on fork lift trucks. Legend: 1.2 = 1.2 meters diameter = 47.3 inches; 1.6 = 1.6 cu. meters = 3530 lbs.; TT = abbreviation of Trockengut—transport or bulk-dry goods transport. Bottom: left, assembled TT-container with closed loading opening. Right, flexible middle part visible, and base with unloading opening.

Figure 17 shows a collapsible plastic and metal container having a capacity of approximately 3000 pounds and a tare weight of 110 pounds. The illustrations were made available by the International Container Bau organization in Hamburg, Germany. It is my understanding that three sizes of these containers are being tested here in the U.S.A. However, the tests are not being made with grease. ■

About the Author

F. W. LANGNER *graduated from the University of Texas in 1926 and joined the Westinghouse organization. In 1931, he joined the Vacuum Oil Co. which later merged with Standard Oil Co. of New York to become Socony Mobil Oil Co. He was technical advisor with his company for three years in Europe and, during the war, acted as chief expeditor of the refinery engineering division in the U. S. After the war, he served as chief project engineer until being named package coordinator in 1950. As his company's corporate member of the Packaging Institute since 1950, he has served as chairman of the Petroleum Packaging Committee and is now chairman of the Committee's metal drum and pail subcommittee. A director of the Packaging Institute, he is a member of the American Management Association, Packaging Planning Council.*



Literature and Patent Abstracts

Process

Manufacture of Fluid Greases Containing Soap-Salt Complexes

A process is described by Morway, Daniels and Spray in U. S. Patent 2,973,321, assigned to Esso Research and Engineering Co., whereby stable fluid lubricants are formed from an oil thickened with the metal salts of acetic and intermediate molecular weight acids. The essential point of the process is that a concentrate containing 20 to 50 per cent of the thickener is homogenized twice before it is further diluted and again homogenized. The finished lubricant is especially useful for marine diesel engines.

For example, a slurry was made of 1776 pounds of hydrated lime and 7600 pounds of an oil having a viscosity of 1200 to 1250 SUS at 100°F. A mixture of 2400 pounds of glacial acetic acid and 576 pounds of acid containing 28 per cent of caprylic, 56 per cent capric, and 16 per cent lauric, was added to the lime slurry at the rate of about 30 pounds per minute. After the final addition of the acid mixture, the mass was mixed at top speed for about two hours after which it was heated to 320°F and held at this temperature for two hours to dehydrate the mixture. At this point 72 pounds of phenyl alphanaphthylamine were added and the mass was cooled to 150°F while 1200 gallons of oil were added. Following this the semi-solid grease was passed twice through a Charlotte mill set at 0.004 inch clearance. Next, 6210 additional gallons of oil were added before another pass through the Charlotte mill.

This gave a fluid with a viscosity of 1766 SUS at 100°F which had a sulfated ash of 5.5 per cent. When tested in a centrifuge for four hours at 1500 rpm, 2.2 per cent of solids separated.

Composition-Testing-Analysis

Report of German Investigations of Lubricating Greases

Ten articles appear in a 1960 issue of *Freiberger Forschungsh*, Section A 164, which section is normally devoted to mining subjects. Notation of the subjects covered and short abstracts follow.

Metal Hydroxide-Soap Thickened Lubricating Greases. Boeck, Keil and Hesse pp. 285-92

Lubricating greases were made from mixtures of sodium or potassium soaps of montan wax fatty acids and hydroxides of either magnesium, barium, calcium, lead, zinc, chromium, manganese, lithium, aluminum, strontium, nickel, tin, cobalt, bismuth and copper, as the thickeners. The proportion of the bodying agents was one mole of soap to one-third mole of the hydroxide.

The introduction of the hydroxides reduced the consistencies, had varying effects on the dropping points, but improved both the water resistance and low temperature characteristics.

Use of Synthetic Fatty Acids in the Production of Lubricating Greases. Keil, Boeck and Hesse, pp. 301-13; Scheel, pp. 314-21.

The first group studied the use of fatty acids produced by the oxida-

tion of paraffin wax and concluded that such fatty acids were not suitable for the manufacture of soap thickeners for oils.

The wax used by Scheel was either that derived from high temperature hydrogenation or the Fischer-Tropsch synthesis and the article is largely a review of attempts at use of fatty acids derived from oxidation of such waxes.

The Structure of Lubricating Greases. Henning, pp. 247-53

Such structure was studied by exchanging the lubricating oil for a solvent in which the gel was insoluble. The solvent was then removed by freezing and drying.

Differential Thermal Analysis of Lubricating Grease. Henning and Trzebowski, pp. 293-300

The effect of increments of stearic acid on the gel formation of sodium stearate in benzene and toluene was investigated. In each case the temperature of gel formation was reduced.

Determining the Hardness of Lubricating Greases. Haussler, Keil and Saxe, pp. 238-46

Using a standard penetrometer, these investigators attempted to eliminate the effects of cone mass and cone angle. In one case, a sample of lubricating grease is raised against the cone until a certain upward force is used. In another case, the cone is lowered into the sample at constant velocity while a determination is made of the difference between the driving velocity and the rate of penetration of the cone.

Water Resistance of Lubricating Greases. Keil, Boeck and Hesse, pp. 275-84

Lubricating greases thickened with soaps of lithium, sodium, potassium, magnesium, calcium, barium, lead, aluminum and zinc, were tested for water resistance. The fatty acids used in the soaps varied in equivalent weights from 276 to 500. The conclusions were that products containing sodium or potassium soaps were the least water resistant; addition of aluminum hydroxide

increased the water resistance; and products made from fatty acids derived from montan wax were the most water resistant.

Testing of Lubricating Greases for Climatic Stability. Kunne, pp. 254-61

Where lubricating greases are used under extreme climatic conditions, penetrations over the expected temperature range are determined. Also, water resistance, corrosiveness, oil separation, evaporation, resistance to mold growth and characteristics at high temperature are determined.

Analysis of Lubricating Greases by Exchange Chromatography. Vamos and Simon, pp. 322-8

In lubricating grease analysis, an improved separation of oil and fatty acids is obtained if cation and anion exchange chromatographic columns are substituted for the usual silica gel columns.

Analysis of Lubricating Greases and Metal Working Oils. Presting, Janicke and Rumpler, pp. 262-74

The cation of the soap is separated and identified by means of ion exchange columns and paper chromatography.

Testing

Laboratory Evaluation of Automotive Gear Lubricants
S. R. Calish, Jr. *Lubrication Engineering* 17, pp 15-23 (1961)

A sequence of laboratory tests is suggested for screening proposed multipurpose gear lubricants. However, a background of service performance is also necessary for such lubricants.

Composition

Corrosion-Resistant Lubricating Greases

According to Caruso (see U. S. Patent 2,971,911, assigned to Shell Oil Co.) lubricating greases, thickened with lithium soaps of 12-hydroxystearic acid, are rendered corrosion-resistant by the addition of a combination of 0.25 to 2 per cent by weight of an oil-soluble imidazoline and 0.05 to 1 per cent of sodium nitrite.

N-hydroxyalkyl or N-aminoalkyl imidazolines are most desirable and a specific compound is 1-N-hydroxyethyl-2-heptadecenyl imidazoline. The presence of these compounds is said to prevent separation of nitrites from the grease compositions. If present, these additives also reduce the necessary proportions of both nitrite and water added to the lubricant. The sodium nitrite is added to the mixture as a ten per cent water solution, no doubt near the end of the processing step.

The imidazolines also act as structure stabilizers in the presence of water. Thus, 100 grams of a lubricating grease consisting of mineral oil thickened with about 8 per cent of lithium 12-hydroxystearate and 10 grams of water were placed in a Shell Roll apparatus and rolled until the lubricant softened to an arbitrary micropenetration of 230. In the case of the product without additives, the time to reach this penetration was 25 hours. However, when the same lubricating grease was tested after the addition of one-half per cent of N-hydroxyethyl-2-heptadecenyl imidazoline and the water, the mixture rolled for over 600 hours before it reached the same micropenetration. The penetration before testing was not stated.

Boron Esters as Antiwear Agents In Lubricating Greases

Certain boron esters were found by Cook (U. S. Patent 2,975,134, assigned to Union Oil Co. of California) to confer antiwear and mild E.P. properties to lubricating greases. The additives are formed by reacting, under dehydrating condi-

tions, equimolar quantities of boric acid and certain dihydroxy alcohols.

Such partial esters are improved by converting to triesters by reaction with monohydroxy alcohol.

For example, 210 grams of boric acid and 100 ml. of water were added to 400 grams of 2-methyl-pentanediol-2,4. The mixture was stirred and cooled in an ice bath, while approximately 100 grams of 98 per cent sulfuric acid were added dropwise. After this addition and 10 minutes more of stirring, the upper layer was separated and permitted to crystallize. This was further purified by recrystallizing from a low boiling naphtha to give the first boron additive. The second additive was formed from 180 grams of the above by refluxing with 90 grams of amyl alcohol in 2 volumes of toluene. A temperature of 230°F was maintained and when a water trap in the reflux line collected no further water, the excess amyl alcohol and the toluene were removed by distillation to give the additive.

A soda base lubricating grease containing approximately 8 per cent of soap was tested on a Falex machine with a jaw load of 100 pounds and for a period of 120 minutes to give 50 wear notches. After the addition of 5 per cent of the first additive to this lubricant, a test under similar conditions showed wear equivalent to 2 notches. A lithium base lubricating grease tested as above showed 48 wear notches but after addition of 5 per cent of the second additive withstood a 500 pound jaw load with only a 6 notch wear.

Antioxidant for Lubricating Greases

Addition of 0.2 to 25 per cent by weight of dibasic lead phosphite to lubricating greases is said to stabilize the products against oxidation. Such a claim is made by Taylor in U. S. Patent 2,975,129. While it is stated that this additive is effective in lubricating greases containing either soap or non-soap thickeners, the examples show the use of di-

basic lead phosphite in lubricants made by thickening oils with clay base materials.

For example, a lubricating grease was made by mixing 5 pounds of SAE 30 oil, 0.4 pound of Bentone 34 and 0.5 pound of dibasic lead phosphite, heating to 160°F and homogenizing. Test panels were covered in part with the above mixture and in part with a commercial calcium soap thickened cup grease. These panels were then exposed to high humidity in a high temperature test chamber. After four months exposure, the cup grease consisted of a dry film while the product containing the dibasic lead phosphite was soft and appeared to have the original consistency.

No comparisons are given of the same compositions with and without the addition of the dibasic lead phosphite.

Water-Resistant Non-Soap Thickened Lubricating Greases

Potter in U. S. Patent 2,975,130, assigned to Union Oil Co. of California, suggests the use of alkyl aryl polyether alcohols to impart water resistance to lubricating greases thickened with colloidal silica or alumina. Compounds useful for the purpose are prepared by reacting an alkyl-substituted phenol with ethylene oxide and are illustrated by Surfonic N-40 and Surfonic N-60.

Either petroleum or synthetic oils can be used in the lubricants. The order of addition of the thickening agent and the waterproofing agent is not critical but it is desirable to disperse the bodying material at temperatures below 200 to 212°F. Finally the mass should be heated to at least 250°F and preferably to 300 to 325°F and then cooled by stirring.

For example, 9 parts of Cab-O-Sil, 1 part of Surfonic N-40 and 90 parts of an oil having a viscosity of 52.5 SUS at 210°F and a V.I. of 86 were mixed at room temperature and then heated to 325°F over a period of ten minutes, followed by cooling while working. The product had a worked penetration of 275. It showed no tendency to breakdown or emulsify in boiling water.

Stabilization of Lubricating Greases Containing Soaps of Oxidized Wax

According to Goff in U. S. Patent 2,974,103, assigned to Texaco Inc., lubricating greases thickened with soaps of oxidized wax can be stabilized against crusting and discoloration by the addition of 0.5 to 5 per cent by weight of alkylated diphenol disulfides.

For example, a lubricating grease consisting of a mineral lubricating oil thickened with a mixed base sodium-calcium waxate soap had an original worked penetration of 344. After one year storage, the product had a worked penetration of 360 but had a hard thin brown crust. The same product after the addition of 1.5 per cent of 4,4′ thio bis(6-tert.butyl meta cresol) had a worked penetration of 342 after one year and had no crust or discoloration.

Non-Soap Thickened Lubricating Greases

Odell and Lyons (U. S. Patent 2,976,237, assigned to Texaco Inc.) suggest a mixture of two pigments, namely ultramarine blue and either PMA, PTA or PTMA pigments as thickening agents for lubricating oils. Such a mixture has the advantage of a lower cost than if the latter pigments alone were used and yet the lubricant has E.P. properties and is oxidation and water resistant. Desirable ratios of the two pigments by weight are 1:3 to 3:1.

The ultramarine blue should be in the form of particles less than 3 microns in diameter. The other pigments, formed by reacting arylamines with phosphomolybdic, phosphotungstic or phosphotungs-

tomolybdic acids, should be in the form of particles less than 5 microns in diameter.

To illustrate the characteristics of lubricating greases made with the suggested mixture of thickeners, a naphthenic base oil of 310 SUS at 100°F was mixed with different pigments and milled twice through a Premier Colloid Mill at 0.002 inch clearance. Using 25 per cent of the organic pigment, the product had a loss of 2.5 per cent in a dynamic water resistance test and the mean Hertz load was 79 kg. When 30 per cent of ultramarine blue was the thickener, the loss due to water was 97.5 per cent and the mean Hertz load 36 kg. With 30 per cent of a 1:2 mixture of ultramarine blue and organic pigment as the bodying agent, the water loss was 2.5 per cent and the mean Hertz load 78 kg. Using 30 per cent of a 1:1 mixture of the two pigments, a lubricating grease resulted with a worked penetration of 377, a dropping point of 424°F and a pressure loss of 3 pounds in 100 hours in an oxygen bomb test.

Characteristics

Extending the Utility of Silicone Lubricants Through Structural Modifications

An article by Schiefer, Awe and Whipple in *J. Chem. Eng.* Data 6, No. 1, pp. 155-60 (1961), while largely a review does have some data relative to lubricating greases in which the fluids consist of modified silicone oils.

Thus, a silicone polymer, prepared with higher phenyl content by incorporating the phenyl group into the chain stopping unit, was thickened with aryl urea, indanthrene blue or copper phthalocyanine. Curves are given showing the effect of radiation on both the unworked and worked penetrations of these lubricating greases. An initial softening in worked penetration is followed by a period of little consistency change and then hardening as the fluid gels.

Mention is also made of fluoroalkyl-containing polysiloxanes compounded into greaselike materials which exhibit resistance to a variety of solvents, chemicals, oxidizers and rocket fuels. Tables give the solubility and resistance to various chemicals of such lubricating greases.

Application

Low-Temperature Torque of Solid Films vs. Lubricating Grease

Torque tests by Devine, Lamson and Bowen, reported in *J. Chem. Eng.* Data 6, No. 1, p. 81 (1961), are of interest.

Retainer surfaces and races of ball bearings were lubricated with a solid film consisting of 71 per cent molybdenum disulfide and 7 per cent graphite, with 22 per cent of sodium silicate as a binder. This film gave a starting torque of 472 gram-cm. at −100°F and 118 gram-cm. at 77°F. In contrast, a lubricating grease meeting specification MIL-G-7421 and used in similar bearings, gave a starting torque of 4764 gram-cm. at −100°F and 177 gram-cm. at 77°F. The running torque was practically the same for both lubricants.

Industry News

Second Lube Blending Plant for Australia

BP Australia is to build a second lubricants blending plant which will be located at its Auburn installation, Sydney. Designed for an annual throughput of 10,000 tons, the new plant will help to meet the increasing demand for BP lubricants in New South Wales.

The first plant, which has been operating at Spotswood near Melbourne since 1959, and the projected one will eventually both be supplied with base lubricating oils from the lubricating oil refinery to be constructed in Western Australia, adjacent to BP's Kwinana Refinery.

Announces New Lubricating Oil Blender

New continuous-flow equipment for precise blending of multiple-ingredient lubricating oils is announced by Girdler Process Equipment division of Chemetron Corp.

Viscosities of finished products are held to within plus-or-minus 0.2 seconds Saybolt Universal by the new system, which accurately proportions the component base oils and costly additives at rates up to several hundred gallons per minute, according to John E. Slaughter Jr., division president.

The equipment includes a console-contained proportioning section, utilized to handle any given number of streams of base oils and additives, and a vacuum blender that delivers a thoroughly blended, dispersed, de-aerated and dehydrated finished lubricating oil to container-filling lines or storage.

Slaughter said the system offers advantages of lower initial investment, reduced maintenance and operating costs and more precise proportioning of complex modern lubricating oil formulas than previously available continuous-process methods. As a replacement for cumbersome batch processes, he said, it reduces manpower, floor space and inventory requirements. The system can be designed to coordinate directly with automatic high-speed container-filling equipment, he said.

Flexibility of design and operation are features of the new system, Slaughter said. Unitized design makes it possible to handle additional streams of additives and base oils by the simple addition of standard proportioning units. Capacity of the blending section can be increased readily without increasing its physical size. Simplified mechanical design of positive-displacement feed pumping, flow regulating and metering devices assures constant high accuracy with one-man operation and minimum maintenance requirements.

Production can be switched from one grade oil to another in a matter of minutes, reducing the need to carry large inventories of a number of finished grades. In normal operation carry-over of oil from a previous grade is so slight that the first container filled with the new grade will be within specifications, Slaughter said.

Flow metering instruments, which read directly in hundredths of gallons delivered for small flow rates and tenths of gallons delivered for larger flow rates, are calibrated for easy proportioning setting and simple temperature correction.

Proportioning sections are made up of multiples of similar units contained in a single console, with original or "add on" units available at maximum delivery rates of 10, 20, 40 and 80 gallons per minute (GPM) per stream of additive or base oil. Proportioning sections and

blenders with outputs of up to 320 GPM are available. Largest present standard is a nine-ingredient system for blending three base oils and six additives.

An area of about 2½ by 15 feet is required for the nine-ingredient proportioning console and 5 by 6 feet for the blender.

Ideal location for the continuous-process blending system, Slaughter said, is at bulk terminal stations where feed can be taken directly from adjacent storage tanks and drums by suction.

Northo Chemical Co. Starts Production At Painesville, Ohio

Northo Chemical Co., a new producer of fat based chemicals, recently started production at Painesville, Ohio. John D. Hetchler, president, is also manager of the chemical division of Werner G. Smith, Inc., and will continue in that capacity, while devoting considerable time to the direction of Northo.

Northo will produce hydrogenated oils, fatty acids, fatty alcohols, fatty acid esters, hydroxy compounds and other chemicals derived from fats and oils. Some of Northo's products will be sold through Werner G. Smith, Inc.

Oil and Grease Plant For Sale or Lease In Cleveland, Ohio

For sale or lease in Cleveland is an oil and grease plant equipped for complete blending and compounding of oils, greases and kindred products, according to information from Francis L. Tenbusch, real estate consultant.

The plant is in the Flats, within a few minutes of the Public Square. It is a three-story building with over 50 tanks, and has a storage capacity of over 8,000 barrels. There are also special tanks and steam-jacketed kettles. The property has a railroad siding and a truck dock.

Interested parties should contact Tenbusch at 1019 Hippodrome Bldg., Cleveland 14, Ohio.

Instant Industrial Colloidal Graphite Dry-Film Lubricant

A new instant industrial colloidal graphite dry-film lubricant called Graphokote 220, packaged in an aerosol container, has been introduced by the Joseph Dixon Crucible Co., Jersey City, N. J. Suitable for "anything that slips or slides," it is particularly recommended for fork lift trucks, sliding doors, winch drums, elevator guides, bell and chain guides and overhead crane rails.

Quick and easy to use, the new product covers all surfaces, protects for longer periods of time, withstands heavy pressures, won't pick up dust or dirt, and is unaffected by temperature changes. Its instant aerosol spray action does away with the old-fashioned oil can and grease brush methods to cover sliding friction surfaces.

Catalog of Centralized Lubrication Equipment Offered by Lincoln

Catalog 82, illustrating and describing its line of centralized lubrication equipment, has been published by Lincoln Engineering Co., St. Louis, division of the McNeil Machine & Engineering Co.

Featured in the 32-page catalog is Lincoln's complete line of lubricant application equipment with descriptions of fully automatic, semi-automatic and manual methods of operation.

High and low pressure lubricant injectors, timing and alarm controls and filler pumps are described along with several pages of installation accessories such as tees, hose, flexible feed lines, coupling studs, etc.

For a free copy, write to Lincoln Engineering Co., industrial sales division, 4010 Goodfellow Blvd., St. Louis 20, Mo.

NLGI's

29th annual

meeting

october 29—

november 1, 1961

rice hotel

houston, texas

ASTM-NLGI symposium . . . five papers and an open discussion on oil viscosity for technical men

Manufacturing Session . . . how to plan, build and install machinery in the modern grease plant

Marketing . . . farm lubrication needs, special product marketing, researcher-marketer empathy.

Special Events . . . the Mr. and Mrs. Early Bird Reception, the Social Hour, Annual Banquet and special events for the ladies

Old Mexico . . . not too far away, for post - meeting tours

People in the Industry

Ralph R. Matthews Dies June 29

Ralph R. Matthews, 77, a long-time veteran of the lubrication industry, died in Kansas City on June 29, after a year's illness. He had retired last year as executive secretary of the Independent Oil Compounders association, after ten years' service. He had been elected honorary executive secretary upon his retirement.

Mr. Matthews had previously been associated with the Shell Oil company and for 21 years he was with Battenfeld Grease and Oil corporation, retiring as executive vice-president. Always keenly interested in intra-industry groups, he was long active in NLGI affairs and served as a member of the Institute's program committee from 1937 through 1943. Mr. Matthews had been an author for the NLGI SPOKESMAN and until his final retirement he was in regular attendance at NLGI annual meetings.

He was a charter member of the Kansas City chapters of SAE and ASLE, and in 1911 he organized the petroleum division of ACS. His association and business contacts gave him a host of friends in this country and abroad, and he was known throughout the world of lubrication.

Named Director of St. Paul Winter Carnival

George J. Rutman, president of Sta-Vis Oil Co. and the Industrial Steel Container Co. of St. Paul, has been appointed a director of the St. Paul Winter Carnival association, it was announced by John H. Donohue III, president of the civic organization.

Mr. Rutman will serve a two-year term as a member of the advisory staff of the nation's largest winter festival. The 1962 Winter Carnival will be held Jan. 26 through Feb. 5.

He has been in charge of Osman Temple Shrine participation in the Winter Carnival for several years and has served many other St. Paul civic activities.

Mr. Rutman also is president of the H. K. Stahl Co., Petroleum Packaging Corp., and the Industrial Steel Container Co. of (Kansas City) Missouri.